Development of a Vigilance Test for High Mental Workload

Ying-Yin Huang (yingyinhuang@ntut.edu.tw)\(^1\), Marino Menozzi (mmenozzi@ethz.ch)\(^{2,3}\), Caroline Favey (caroline.favey@unine.ch)\(^3\)

\(^1\) Department of Industrial Engineering and Management, Taipei Tech, Taipei, Taiwan  
\(^2\) Department of Health Sciences and Technology, ETH Zurich, Zurich, Switzerland  
\(^3\) Faculty of Science, University of Neuchâtel, Neuchâtel, Switzerland

ABSTRACT

Vigilance performance has become an important factor in modern work. In a previous publication, we presented a test for screening visual vigilance performance and satisfying practical requirements of occupational medicine, such as an ecologic valid test setting, a short duration of testing, a test designed for detecting weak performers and offering comparative vigilance performance data (N=150) of the normal population. The test requires an observer to detect the digit “3” in a six-digit number, which is flashed over a distracting video background. From collected answers, the vigilance performance is computed by means of the theory of signal detection and for three different locations of the six-digit number in the visual field, which are on the left, in the center, and on the right visual field.

After a series of successful applications of the test in many different circumstances, various interests from research and practice arose, wishing to expand the test in order to assess vigilance performance in high performing observers. In order to accommodate this demand, the level of difficulty of our vigilance test was increased. This was achieved by shortening the exposure duration of the target presented in the vigilance test from originally 300 ms down to 200 ms.

In the here presented study, an experiment is reported, aiming to establish comparative data of the normal population taking the vigilance test at the higher and at the lower (original) level of difficulty as well. Since vigilance performance is affected by age and the top performers have been found to be younger than about 40 y, a population of 60 observers ranging between 19 y and 40 y was used in the experiment. In half of the population, the shorter exposure time of the target was administered first.

Statistical analysis of vigilance performance clearly showed an effect of exposure time. When shortening the target exposure time from 300 ms to 200 ms, the average sensitivity d’ drop from 2.7 (SD=0.9) to 1.2 (SD=1.2). The number of times at which peak values for d’ were recorded was reduced when shortening the exposure time of the target. A reduction of the number of peak records appeared for targets presented in the central visual field (from 19 times down to 7 times when shortening the exposure time from 300 ms to 200 ms) as well as for targets presented in the peripheral visual field (from 7 times to 0 times).

Given above described results, we conclude that reducing the exposure time of the target in the test for assessing vigilance performance from 300 ms to 200 ms, the difficulty of the vigilance test could be significantly increased. Therefore, the test appears more adequate to be used for testing people trained for high stress, such as surgeons. With the improved test we plan to investigate the effectiveness of ergonomic improvements in workplaces at which workers are exposed to a high level of stress. Among such measures are the management of rests, strategies of work and system optimizations in general.

Keywords: Vigilance, Visual screening, Attention, Occupational health and safety, Natural visual environment

1. Introduction

Attention, an executive function of information processing in man (Smith EE et al., 1999), facilitates the selection of information of particular interest. Thanks to attention, non-relevant information is discarded before being processed. The mechanism therefore helps coping efficiently with the limited resources of information processing in man, such as the limited storage capacity of the visual short term memory (Bundesen C, 1990). In the recent past, an important body of literature has
evolved reporting about how the attentional mechanism influences the selection of stimuli of interest (Carrasco M, 2011). Apart individual factors, such as age or visual acuity, physical properties of a stimulus, such as the location of the stimulus in the visual field (Stugaard CF. et al. 2016), have been found to affect attentional performance. In everyday life, attention is executed in a rather complex environment, requiring far more factors than the stimulus location to be considered simultaneously when determining performance. For instance, a task could require the observer to maintain visual attention for a prolonged duration, such as in the case in air traffic control or when monitoring processes in a nuclear power station. We will use the term “vigilance” further on to refer to the prolonged use attention. In an everyday situation, attention is executed in a visual natural, therefore complex, environment, which is particularly challenging the ability to discriminate relevant from non-relevant information. In addition, other, non-visual related factors may affect vigilance performance, such as for instance stress (Starcke W. et al., 2016), a factor frequently present in the modern occupational world.

Many methods for testing attention performance have been described in the past as for instance the d2 test of attention (see e.g. Bates ME et al., 2004) or the elevator test in the test of everyday attention TEA by Robertson, Ward, Ridgeway and Nimmo-Smith (1994). However there are only few tests of visual attention, in which attempts have been made to render the visual environment in the test similar as the everyday practice. An example for such a test is the UFOV test (Ball K et al., 1993) for testing driving skills, in which targets, cars and trucks have been adapted to real world targets. However, the UFOV does not provide a naturalistic visual background. In conclusion, there is a lack of tests of visual attention, in which a complex, distracting visual environment has been considered.

In a previous work (Menozzi M. et al., 2012) we have developed a test for assessing vigilance performance (fig. 1). The test was designed to fit ecological validity of occupational practice as well as to enable an easy way to screen for low performers in vigilance. In our test, a six-digit number is presented on the monitor for a duration of 300 ms at one of the three, randomly selected locations: left visual field (-15.3° in periphery), central visual field or right visual field (+15.3°). The task of the observer is asked to report whether or not the digit “3” was included in the presented six-digit number. Throughout the test, which is lasting 4 min, a video of a car drive as seen from a driver is displayed in the background of the monitor. After collecting a total of 72 responses, vigilance performance is computed based on the signal detection theory (Macmillan NA et al., 2005). As main result of the computation, the test provides the vigilance performance in terms of sensitivity d’, for the left, center and right visual field as well as the vigilance performance d’ based on data pooled across the three locations of measurement. Data collected with the test and using a normal population (N=150) with an age ranging between 15 and 65 years, as well as further details on the test have been reported in a previous publication (Menozzi M. et al., 2012). Up to date, the test has successfully been used in various applications, such as in practice of occupational medicine, in the assessment of vigilance performance in car drivers who are influenced by drugs such as for instance alcohol or other narcotics, in the assessment of complexity of traffic situations, or in the determination of effects of various rota-shifts and night work-shifts. Due to its successful and simple application, there has been a growing interest in applying the test for assessing vigilance performance in high performers, such as is the case in surgeons trained to perform complex surgery, in personnel working for security inspections in aviation, or in sports.

---

Figure 1. Setup of the vigilance test (left) and a two sequences of the test as seen by the participant (center and right pictures).
2. Method

The aim of this study was to adjust the settings of above described vigilance test, in order to enable to assess vigilance in high performers, as opposed to the original setting, with which vigilance is assessed in low performers. By reducing the exposure time of the target from 300 ms to 200 ms the test was rendered more difficult, therefore more adequate for testing vigilance in high performers. For convenience, the assessment of comparative performance data was restricted to a population of young participants, for which, and according to our previous study (Menozzi M. et al., 2012), vigilance performance is at a peak level.

A total of 60 participants of an age ranging between 19 y and 40 y (average age 28.3 y, SD = 3.5 y, 48 m, 12 f) took part in our comparative study. All participants had normal or corrected to normal visual acuity. Each participant took the above described vigilance test two times, once, with the exposure duration of the target set to 300 ms, as in the original version of the test and another time, in which the exposure duration was set to 200 ms. Half of the participants started with the 300 ms version of the test. Before starting a test, participants were given a 10 trials practice. After completing the first test, participants took a short (1-2 min) break.

Participants were informed about the purpose and the methods used in the study. Written consent was obtained before starting the experiment. Demographic data (age, gender) was recorded by means of a short questionnaire. The questionnaire included a question about drug consumption (“Did you take any drugs during the last 24 hours (medicine or other substances)?”. Persons responding the question on drug intake positively were not included in this study. All participants completed the two tests within about 12 to 15 min. Participants were rewarded with a bar of delicious Swiss chocolate.

3. Results

Vigilance performance as reported in sensitivity $d'$ is shown in Fig. 2. The left most pair of bars report average $d'$ pooled across all locations of the visual field, in which the six-digit numbers were presented (left, center, and right). The left bar of the left most pair refers to vigilance performance assessed using the more difficult level of the test, i.e. in which an exposure duration of the target of 200 ms was used, whereas the right bar denotes performance assessed using the 300 ms exposure duration. The other pairs of bars show results for the locations left, center and right visual field. Error bars denote 1 SD. Results were analyzed by means of two ANOVAs. In a first ANOVA the vigilance performance “$d'_{All}$” was investigated which is computed based on data pooled across all locations. In the second ANOVA, performance in the three locations was considered separately. In the first ANOVA a the two-level factor difficulty and a three-level factor location were considered as within-subject factors and the sequence of taking the tests was considered as a between subject factor. Results of this ANOVA show that exposure time (F(1) = 206.27; p = 0.000; partial eta square = 0.781) significantly affects $d'_{All}$. The interaction between exposure time and the sequence of testing also significantly affects $d'_{All}$ (F(1) = 2.896; p = 0.000; partial eta square = 0.244). As for the second ANOVA, exposure time (F(1,2) = 64.950; p = 0.000; partial eta square = 0.778) as well as location (F(2,1) = 88.077; p = 0.000; partial eta square = 0.603) were found to exert a significant effect on vigilance performance. As shown by Fig. 2, effect of exposure time is more pronounced in the visual periphery. At increased load of information processing, resources for peripheral processing are reduced in order to keep performance high in the central visual field.

![Figure 2. Vigilance performance across the visual field and for the easy (300 ms exposure duration) and difficult (200 ms exposure duration) level of the test. Left most pair of bars denote the average performance across the visual field for the difficult and easy test level. Error bars denote 1 SD.](image)
The number of peak values for d’ was reduced considerable when shortening the exposure time of the target from 300 ms to 200 ms. The reduction of the number of peak records appeared for the targets presented in the central visual field (from 19 times down to 7 times when shortening the exposure time from 300 ms to 200 ms), as well as for the targets presented in the peripheral visual field (from 7 times to 0 times).

4. Conclusion

Given above described results, we conclude that reducing the exposure time of the target in the test for assessing vigilance performance from 300 ms to 200 ms, the difficulty of the vigilance test could be significantly increased. Therefore, the test appears more adequate to be used for testing people trained for a high level of vigilance performance, such as is the case in surgeons. With the improved test we plan to investigate the effectiveness of ergonomic improvements in workplaces at which workers are exposed to a high level of stress. Among such measures are the management of rests, strategies of work and system optimizations in general.

Acknowledgements

The authors wish to thank all participants who have contributed to this experiment as well as ETH Zurich, University of Neuchâtel and Taipei Tech for supporting this research.

References


